

- (6) M - Identify uncertainty in measurements  
(7) S - Calculate percentage uncertainty  
(8) C - Combine absolute and percentage uncertainty

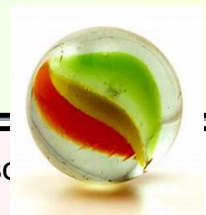


## Lesson 4. Uncertainty 2

### STARTER:

Measure the diameter of the marble with a) micrometer and a b) caliper.

Write the value and the percentage uncertainty of each.



Kilo  $10^3$

Compare the % uncertainty of both and suggest reasons for the difference

Mega  $10^6$

Explain the difficulties you encountered when measuring the marble.

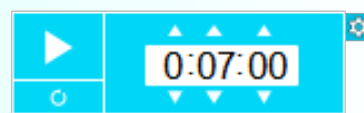
Giga  $10^9$



Key point

a)  $15.525 \text{ mm} \pm 0.003\%$   
b)  $15.75 \text{ mm} \pm 3\%$

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## Percentage uncertainty - A measure of accuracy



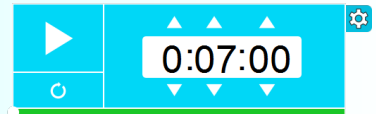
$$\text{percentage uncertainty} = \frac{\text{(absolute) uncertainty}}{\text{measured value}} \times 100\%$$

(give students one high volume one low volume)

Example measuring cylinder (from starter) -  
Find the % uncertainty of the 2 values in the starter.  
Comment on the answer....

16.5 ml.      1.5%  
5 ml.      5%

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## Combining uncertainty



Key  
point

In a calculation, if several of the quantities have uncertainties then these will all contribute to the uncertainty in the answer. The following rules will help you calculate the uncertainty in your final answers.

1. When quantities are added, the uncertainty is the sum of the **absolute** uncertainties. +
2. When quantities are subtracted, the uncertainty is also the sum of the **absolute** uncertainties.

Example



John 186cm  $\pm$  0.1m

Alice 175cm  $\pm$  0.1m



If Alice stands on John's head, what is the combined height?

3.

$$361 \pm 0.2$$

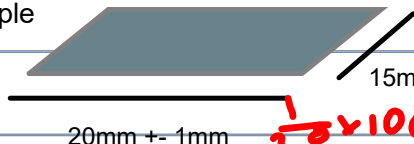
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When quantities are multiplied, the total percentage uncertainty is the sum of the percentage uncertainties.

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When quantities are divided, the total percentage uncertainty is also the sum of the percentage uncertainties.

Example



20mm  $\pm$  1mm

15mm  $\pm$  1mm

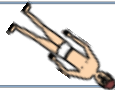
Find the area, including the absolute uncertainty

$$a = w \times l = 15 \times 20 = 300 \pm 12\%$$

Handwritten calculations:  
 $\frac{1}{15} \times 100 = 6.6\%$   
 $\frac{1}{20} \times 100 = 5\%$   
 $6.6 + 5 = 11.6$

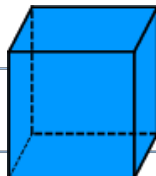
When a quantity is raised to the power  $n$ , the total percentage uncertainty is  $n$  multiplied by the percentage uncertainty – for example, for a quantity  $x^2$ , total percentage uncertainty =  $2 \times$  percentage uncertainty in  $x$ .

Example



Fred's pool is a perfect cube of length (L) = 8m  $\pm$  0.05m

Find the volume of the cube and the uncertainty.



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**Mini practical:** Take measurements to find the density of copper/steel/ aluminum including the uncertainty.

Show full working out for each calculation.

**Kilo  $10^3$**

**Mega  $10^6$**  Ex: Ex: How do you reduce your

**Giga  $10^9$**  percentage uncertainty?



Key  
point

density of copper =

percentage uncertainty =

density of aluminum =

percentage uncertainty =

density of steel =

percentage uncertainty =

Aluminum

2712

$\text{kgm}^{-3}$

Steel

7850

Copper

8940

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## Plenary



A flea is measured to be 1.2mm with a micrometer with resolution 0.1mm

a) Write the measurement including the uncertainty.



b) calculate the percentage uncertainty.

$1.2 \text{ mm} \pm 0.05 \text{ mm} \checkmark$   
 $\%u = \frac{\Delta u}{u} \times 100$   
 $4.16\% \approx 4.2\%$

Ex: Why is percentage uncertainty consider more useful

What are the limitations in this value of uncertainty?

